A survey of ground-dwelling mammals inhabiting forests of the southwestern slopes, New South Wales

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ABSTRACT

State Forests of the southwestern slopes of New South Wales were surveyed for ground-dwelling mammals utilizing hair traps (42 sites), small mammal traps (11 sites), nocturnal searches (253 sites), scat and animal sign observations, opportunistic observations and records from unpublished studies in the region. A total of 13 indigenous and 10 exotic ground-dwelling mammal species were identified. No threatened species were encountered, although some evidence suggesting the presence of a Potoroo *Potorous* sp. and Smoky Mouse *Pseudomys fumeus* was found in Bago and Maragle State Forests. Hair tube trapping (1 170 large traps for an average of 18 nights each and costing 226 person hours) revealed the presence of nine species/genera. Swamp Wallabies *Wallabia bicolor*, were the most commonly detected species. Small mammal trapping in swampy environments of Bago and Maragle State Forests (1 100 trap nights costing 52 person hours) detected the presence of Bush Rat *Rattus fuscipes*, Dusky Antechinus *Antechinus swainsonii* and Brown Antechinus *Antechinus stuartii*. *Rattus fuscipes* proved to be abundant in some localities. Records made by nocturnal survey (253 sites costing 306 person hours) revealed 14 ground-dwelling mammal species, notably Long-nosed Bandicoot *Perameles nasuta*. All the techniques were judged to be of value for broad forest surveys as no technique covered all species. Hair trapping had the greatest limitations in this study but is still of value if the method is used as a preliminary technique.

INTRODUCTION

The ground-dwelling mammals of the south-west slopes have been little studied. The only published studies from the region are of *Macropus giganteus* (Jaremovic 1984) and *Vombatus ursinus* (McIlroy 1973). Other surveys conducted in the area have not been published, notably that by Bruce Gall in the early 1980s. The region contains habitat suitable for a number of species listed under the New South Wales *Threatened Species Conservation Act 1995*.

Tumbarumba Hardwoods Management Area includes 19 State Forests, 18 of which were sampled for ground-dwelling mammals during this study. The forests range from tall and moist at high elevation (>900 m) in the east through to dry woodlands of eucalyptus and cypress pine at low elevations (<600 m) in the north-west.

Uses of the forests include timber production (cabinet timber through to fence posts and fire wood), grazing (mostly cattle in the eastern areas), and recreation (including four-wheel driving, horse riding, fishing and other outdoor recreations). All of these activities have impacts on the forest environment that may influence the distribution and abundance of ground-dwelling mammals. Impacts include undergrowth destruction, weed introductions and feral predator releases.

The aim of the present study was to broadly document the regional distribution and abundance of ground-dwelling mammals in the forests of the region. Special emphasis was placed on methods that would be likely to detect species listed as threatened. Bago and Maragle State Forests were sampled more intensely to form a baseline of data for use in future studies. Companion studies in the region by Kavanagh and Stanton (1998) of nocturnal birds and arboreal marsupials, Law *et al.* (1998) of bats and Lemckert (1998) of herpetofauna also contribute to the baseline data.

Additionally, the comparative effectiveness of the methods used in this survey were evaluated. A comprehensive assessment of hair trapping compared to other methods of detecting mammals has not previously been undertaken. Other authors have presented comparisons of hair trapping data with other data collection methods. Lindenmayer *et al.* (1994) compared hair trapping results with the results of identified scats left in the same hair traps, concluding that the scats formed a valuable part of the data. Guy (1996) compared the cost effectiveness of hair trapping with conventional trapping and spotlighting but did not consider the practical limitations of the techniques. Comparisons of methods by effort and results within studies such as this may prove useful in lieu of a comprehensive assessment.

METHODS

Study area

Approximately 145 000 hectares of eucalypt forest within 19 State Forests on the south-west slopes of New South Wales form the Tumbarumba Hardwoods Management Area (shown in Fig. 1). A detailed description of the study area has been provided by Kavanagh and Stanton (1998).

Habitats for ground-dwelling mammals range from tall moist forests in the east through to isolated fragments of dry woodland surrounded by cleared agricultural land in the west. Understorey ranges from none, through to dense heathy thickets. Much of Bago, Maragle and Buccleuch State Forests have an open understorey with only a ground cover of grass, primarily *Poa* sp. Patches of heathy understorey or acacia regeneration are scattered through the landscape and the gullies are frequently choked with thickets of Blackberry *Rubus* sp. The western forests of the region generally have an open grassy understorey, however, about a third of Woomargama State Forest has a tall, dense understorey of eucalypt regeneration or tall heathy plants.

Timber management has been intensive in the forests in the east of the region. Heavy logging and tree culling has produced dense stands of even aged regeneration, both of Alpine Ash *Eucalyptus delegatensis* and various smooth-barked eucalypt species. In some of the western forests, sleeper cutting of ironbark has had a significant effect, however, wildfires and hazard reduction burning may be the heaviest impact on the ground-dwelling mammal habitats of the western forests. A particularly severe wildfire swept through Woomargama State Forest in the early 1990s.

Trapping was carried out only within State Forests of the region, however observations and historical records from anywhere within the region have also been included. Data collected during a nocturnal survey included sites in Kosciuszko National Park and from vacant Crown land.

Stratification and survey methods

A number of different methods were used to detect groups of target species. Hair traps and box traps were the primary sampling method. Additional observations made during the nocturnal bird and arboreal mammal survey (Kavanagh and Stanton 1998) were valuable for the larger species. Observations of animal signs such as scats or prints were noted and/or collected/photographed. Carnivore scats were collected opportunistically throughout the survey. Collected scats and their contents were identified.

Hair traps

Large hair traps (square section tubes 100 mm wide) were used to sample all State Forests in the region except Green Hills. Hair traps set on the ground were placed in transects of 10 traps at 20 m intervals. Each site comprised three transects with one transect being set on a ridge, one on the mid-slope and one in a gully, with each running (as near as possible) parallel to each other. The sampling period was through April and May 1995. Hair traps were set for an average of 18 days (16 days minimum, 21 days maximum). On each transect five traps were baited with red meat and the alternate five were baited with a mixture of oats, peanut butter and a small quantity of honey.

Stratification of these transects was achieved by two methods. Thirty-seven sites with three transects at each site (111 transects), were located evenly over the range of geology and elevations within each of the larger State Forests. These were also set to stratify by local topography with the transects at each site being set one in a gully, one on a mid-slope and one on a ridge. Alternatively, a single site was selected in the smaller State Forests based on the dominant habitat features and accessibility.

A further six transects were located singly or in pairs in locations that had vegetation types or topographic features of particular interest, for example swamps or areas with dense understorey. Thus the total number of large hair traps set was 1 170. Figure 1 shows the site locations.

It was considered that dry forest with box, ironbark and stringybark generally occurring below 700 m may provide suitable habitat for the Brush-tailed Phascogale *Phascogale tapoatafa* as records of this species from south-eastern New South Wales (NSW NPWS Wildlife Atlas) and northeastern Victoria (Menkhorst 1995) have usually come from similar dry forest types. These environments were additionally sampled with small hair traps (35 mm diameter) set approximately two metres up tree trunks. Five small hair traps baited with the oats, peanut butter and honey mixture were set at approximately 40 metre intervals along each of these transects. A total of 50 transects (250 traps) were set for an average of 18 nights each.

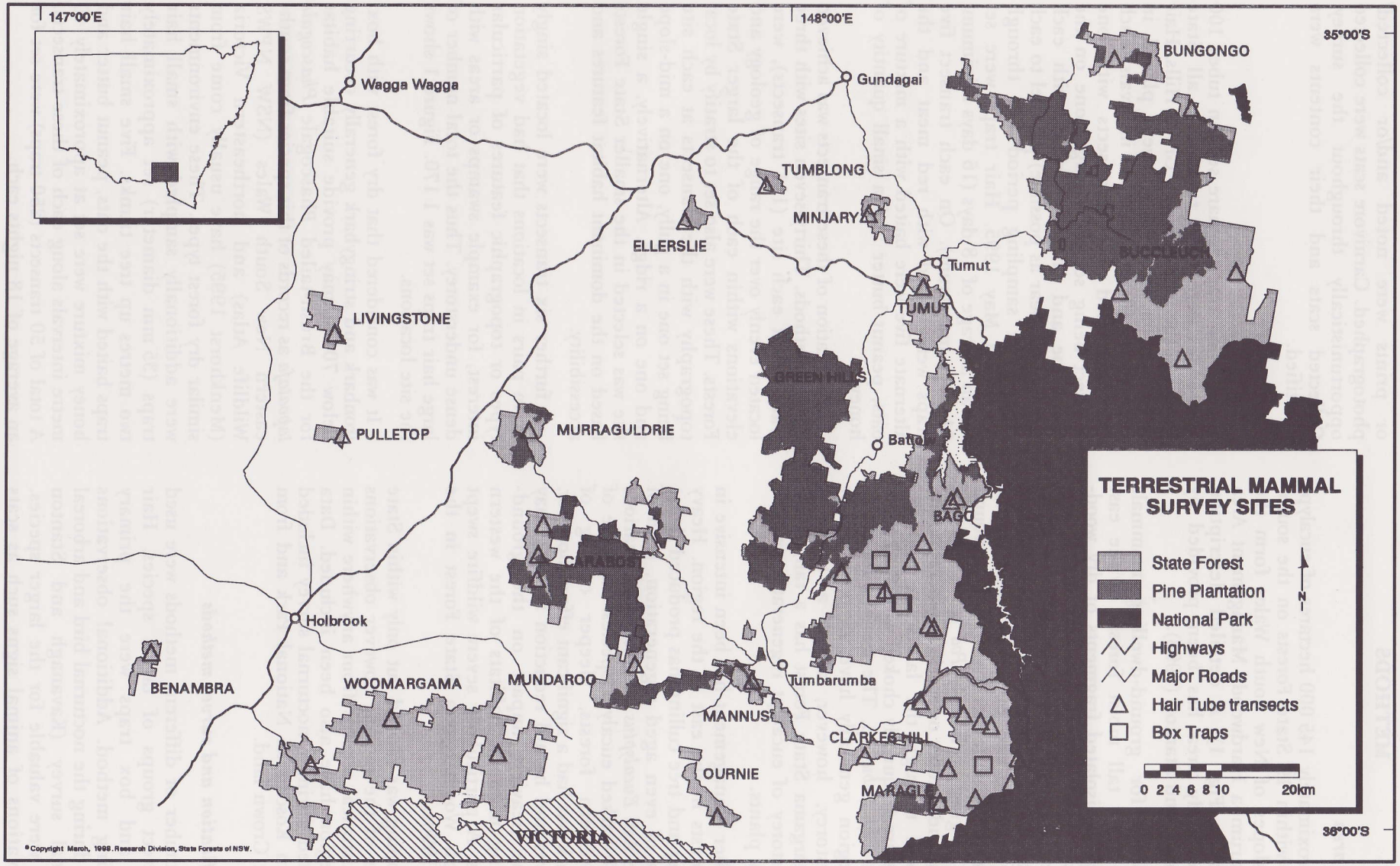

Figure 1. Terrestrial mammal survey sites.

Small mammal traps

The Broad-toothed Rat *Mastecomys fuscus* was expected to occur in State Forests but would not have been sampled adequately by the hair trapping strategy. *Mastecomys fuscus* inhabits a range of environments from alpine herbfield to coastal tussock grassland. In alpine areas above 1 000 m it occurs in tall alpine herbfield, fen, bog, heath and woodland (Menkhorst 1995). In sub-alpine areas below 1 000 m it occurs in areas with a dense, wet understorey, where patches of sedgeland and fernland occur on creek flats or gaps in the forest canopy (Warneke 1960; Wallis 1992). They are also found in the adjacent Snowy Mountains (Happold 1995).

To sample appropriate environments in Bago and Maragle State Forests, seven transects of Elliott brand aluminium box traps (90 mm × 100 mm × 325 mm) were set for four nights each between 23 and 28 April, 1995. The seven transects comprised three transects of 25 traps and four transects of 50 traps depending on the size of habitat available for sampling. Thus 1 100 trap-nights were used. Oat/peanut butter/honey baits were used for all traps. Areas were trapped where Broad-toothed Rats potentially occur. These were in drainage lines or depressions where the following vegetation types occurred; alpine and sub-alpine herbfields, bogs, heaths, and sedgelands. All locations were over 900 metres elevation. Figure 1 shows the trap line locations.

Environmental measurements

The following environmental variables were measured for each transect. Approximate Australian Map Grid co-ordinates and elevations were determined using 1:25 000 topographic maps. Topographic position, slope and aspect were determined at each site. Basic vegetation structure and floristic composition was measured and noted.

Geology was determined from 1:250 000 geology maps, primarily the Wagga Wagga Metallogenic/Geologic Sheet (Degeling 1977). A corrected map for Bago-Maragle was available which modified the geological typing for some areas. Sites were placed away from geological boundaries.

Hair and scat analysis

Hair samples and scats/scat contents were identified by Barbara Triggs using the trichology techniques advanced by Brunner and Coman (1974). Many samples could not be identified to species level because of insufficient sample size, the nature of hairs produced by some genera/family of mammals or because of geographic variation in the species group and a lack of local reference material with which to compare the trapped hair. These first two limitations apply to almost any hair trapping study and the third to any study conducted in a previously unsurveyed area as with this study. Data were presented to the greatest level of confidence possible.

Rock-wallaby searches

Searches for Brush-tailed Rock-wallabies *Petrogale penicillata,* or their signs, were conducted in the east of Bago State Forest (Bundong Falls), the south of Woomargama State Forest (Phillis Fire Trail) and on the prominent rock faces of Benambra State Forest. In each case, prominent steep rocky habitat was searched from a suitable vantage point with 10 × 38 binoculars and a scat search was made at the base and/or top of the incline depending on accessibility. Approximately 10 hours search time was spent between November 1994 and May 1995.

Data analysis and presentation

Contingency chi-square analysis (Zar 1984; SAS 1986) using presence/absence data for species were used to determine the levels of association between species occurrence and the topographic position. These analyses were performed across the 117 transects assuming independent samples. Only two ground-dwelling species had sufficient records for the contingency chi-square test (using three categories).

The effectiveness of bait used was tested with Fishers Exact Test (Zar 1984; SAS 1986) but could be performed on only 108 transects as nine were retrieved without proper reference to the bait used. This sample was split between the two bait types (thus representing sets of five traps) giving 216 presence/absence samples which were considered as independent for the purposes of the analysis. Four species/genera of ground-dwelling mammals had sufficient numbers of records for use in the Fishers Exact Test. Bait preferences of *Trichosurus* sp. were also tested.

The effort for each method was calculated as follows. (Bait preparation, specimen/hair identification and trap cleaning/maintenance are not included in the calculations.) All three methods were calculated for each State Forest sampled.

Hair traps. Effort = Number of Traps × (Trap prep. + Setting + Collecting + Remove tape) + Number of sites × Travelling time × 2 (people)

Trap preparation and baiting	=	2 *min/trap*
Setting	=	1 min/trap
Collecting	=	1 min/trap
Removing tape	=	2 min/trap
Travelling time	=	1 hour/site × 2 people

Small Mammal Traps. Effort = Number of Traps × (Setting and baiting + Clearing (× 4) + Collecting) + Number of sites × Travelling time

Setting and baiting	=	2 min/trap
Clearing	=	1 min/trap (4 times)
Collecting on last day	=	1 min/trap
Travelling time	=	$2^1/_2$ hours/site × 1 person

Nocturnal survey. Effort = Number of sites × (Survey + Travelling time)

Survey	=	45 min/site
Travelling time	=	30 min/site × 1 person

RESULTS

Large hair traps revealed the presence of nine ground-dwelling species/genera. These were *Antechinus* sp. (9 samples), *Vombatus ursinus* (2), *Wallabia bicolor* (127), small conilurine rodents (3), *Rattus fuscipes* (22), *Canis* sp. (20), *Felis catus* (4), *Bos taurus* (22) and *Capra hircus* (1). *Trichosurus* sp. (114) and *Pseudocheirus peregrinus* (1) were also detected, however as these species are primarily arboreal marsupials they are considered in more detail by Kavanagh and Stanton (1998).

The small tree-mounted hair traps did not reveal any records for species that were not already revealed by the large ground set traps. Only *Antechinus* sp. and *Trichosurus* sp. were detected by small tree mounted hair traps (three samples each).

Small mammal trapping detected the presence of *R. fuscipes, Antechinus swainsonii* and *Antechinus stuartii* in the swamp communities sampled. *R. fuscipes* proved to be abundant in some localities with trapping rates up to 44% on some nights. The overall trap success rate was 10.5%.

Scat collection revealed the presence of domestic *Canis familiaris* and *Vulpes vulpes* from 37 scats. Prey species detected in the *V. vulpes* scats included *Antechinus* sp., *V. ursinus* and *Oryctolagus cuniculus*, all of which were identified by other means in those areas. No records of *Petrogale penicillata* exist from the region, the nearest being from Yarrangobilly Caves. No individuals or signs were detected during this survey.

The known distributions of ground-dwelling mammal species across the Tumbarumba Hardwoods Region are presented in Table 1. *Antechinus* species are presented together because the three species known from the region were not identifiable from the hair samples. While identifying *A. swainsonii* and *A. stuartii*, small mammal traps were only used in swampy areas in Bago and Maragle State Forests. The Yellow-footed Antechinus *Antechinus flavipes* exists in the western parts of the region (Australian Museum database and NSW NPWS Wildlife Atlas).

Three road killed specimens of *Macropus rufogriseus* (all collected along the Elliot Way between Bago and Maragle State Forests) were weighed by the author. Two males weighed 28 kg and 22.3 kg while a non-lactating female weighed 19.3 kg. All these were large specimens when compared with the weights given by Calaby (1995) of 26.8 kg maximum for males and 15.5 kg maximum for females.

Hairs from small conilurine rodents that may have been *Mastacomys fuscus* or a *Pseudomys* species were obtained at two sites in Maragle State Forest and one site in Bago State Forest. In the vicinity of the Maragle State Forest records, the author spotlit two mice at close quarters. The individuals were both a plain mid-grey above and pure white below with a similarly bi-coloured tail. One individual was seen to climb crudely in the shrubbery consisting primarily of the pea *Davesia latifolia* and other heathy plants of a moderate density. The author believes that these were most likely the Smoky Mouse *Pseudomys fumeus* which are known to occur in an adjacent area of Victoria (Menkhorst 1995). *Pseudomys fumeus* is listed on Schedule 1 of the New South Wales *Threatened Species Conservation Act 1995*.

Table 1. The distribution of ground-dwelling mammals by State Forest (native forest area) within Tumbarumba Hardwoods Region. X indicates a record from this study. O indicates records from other studies. Lowercase indicates the record was outside the State Forest but nearby. Records were collated from hair trapping (117 transects), box trapping (7 transects), nocturnal surveys (253 sites) (Kavanagh and Stanton 1998), opportunistic records (including scats) collected by survey personnel during the preceding surveys and unpublished database records supplied by NPWS, CSIRO, Australian Museum and Darren Boss (Charles Sturt University; pers. comm.).

Species/State forest	Bago	Woomargama	Buccleuch	Maragle	Carabost	Tumut	Mundaroo	Murraguldrie	Bungongo	Livingstone	Ournie	Clarkes Hill	Mannus	Minjary	Benambra	Green Hills*	Ellerslie	Pulletop	Tumblong
Ornithorhynchus anatinus						O			O				X						
Tachyglossus aculeatus	X	X	X	X		O		O	O	O					O				
Antechinus sp.	X	X	X	X		X	X	X	O	X		X	X		o				
Perameles nasuta	X			X															
Vombatus ursinus	X	X	X	X	X	X		X	X						x				
Macropus giganteus	X	X	x	X	X	X		X	X	X	X	X		X	X	X	X	X	
Macropus robustus	o					X			O									X	
Macropus rufogriseus	X	o	X	X			X		X		X								
Wallabia bicolor	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Small Conilurine Rodents	X			X															
Hydromys chrysogaster	o					O													
Rattus fuscipes	X	o	X	X	X							X							
Mus musculus		o					o											O	
Oryctolagus cuniculus	X		X	X				X		O					X		X	O	X
Canis sp.	X	X	X	X						X					X				
Vulpes vulpes	X	X		X	o		o				X	x							
Felis catus		x		X	X	X													
Equus caballus	X			X															
Bos taurus	X			X															
Capra hircus													X						
Sus scrofa		X		X								X							
No. Native Species	11	7	7	9	4	8	3	5	8	4	3	4	3	2	5	2	2	3	1
No. Exotic Species	5	5	2	7	2	1	2	1	0	2	1	2	1	0	2	0	1	2	1

* Green Hills State Forest had no targeted surveys for ground-dwelling mammals.

Effectiveness of trapping and detection methods

No significant differences in relation to trap placement by topographic position are apparent for *W. bicolor* or *R. fuscipes* (Table 2) although the latter was found over twice as often on gully transects compared with ridge transects.

Trichosurus sp. and *W. bicolor* showed a significant preference for the oat bait compared to the meat bait while *R. fuscipes*, *Canis* sp. and *B. taurus* showed no significant bait preference (Table 3).

The three *Macropus* species present were not detected by hair traps despite *W. bicolor* being

Table 2. Topographic position for two hair trapped ground-dwelling species. Data represent the percentage of transects where each species was recorded. n/s = not significant.

Species	Position Gully	mid-slope	Ridge	Number of transects	χ^2 value	*P*-value
Wallabia bicolor	62.5%	55.2%	51.3%	66	1.04	n/s
Rattus fuscipes	25.0%	13.2%	10.3%	19	3.55	n/s
Total number of transects	40	38	39	117		

Table 3. Bait effectiveness in hair traps for the five most commonly trapped species/genera. Bait values for each species represent the percentage of the sample for that bait. n/s = not significant.

Species	Bait Meat	Oats	Number of transects	χ^2 value	*P*-value
Trichosurus sp.	10.2%	20.8%	67	11.45	<0.01
Wallabia bicolor	6.5%	24.5%	67	32.91	<0.01
Rattus fuscipes	3.7%	5.1%	19	0.52	n/s
Canis sp.	3.7%	3.2%	15	0.07	n/s
Bos taurus	2.8%	4.2%	15	0.65	n/s
Total number of transects	108	108	216		

Table 4. Effort (person hours) and numbers of ground-dwelling mammal species/groups found by each detection method.

State forest	Native timber Area (ha)	Nocturnal survey* Effort (hrs)	Nocturnal survey* No. sp.#	Hair tube Effort (hrs)	Hair tube No. sp.	Box trap Effort (hrs)	Box trap No. sp.	Opportunistic No. sp.	Other studies No. sp.
Bago	37 000	110	7	44	5	27.5	3	9	3
Woomargama	32 000	33.75	4	23	3	N/A	N/A	3	5
Buccleuch	26 000	42.5	2	21.5	3	N/A	N/A	4	1
Maragle	19 800	47.5	6	41	5	24.17	3	11	0
Carabost	3 700	10	4	16.5	3	N/A	N/A	4	0
Tumut	3 400	6.25	1	5	2	N/A	N/A	1	9
Mundaroo	3 000	8.75	1	6.5	2	N/A	N/A	2	0
Murraguldrie	3 000	6.25	2	6.5	2	N/A	N/A	2	6
Bungongo	2 700	6.25	3	6.5	1	N/A	N/A	3	9
Livingstone	2 180	7.5	1	5	2	N/A	N/A	2	6
Ournie	2 170	3.75	3	6.5	1	N/A	N/A	4	0
Clarkes Hill	2 100	3.75	2	6.5	3	N/A	N/A	3	0
Mannus	2 000	5	1	6.5	3	N/A	N/A	2	0
Minjary	1 400	3.75	0	5	2	N/A	N/A	2	0
Benambra	1 400	3.75	2	6.5	2	N/A	N/A	3	0
Ellerslie	900	3.75	1	6.5	1	N/A	N/A	1	0
Pulletop	760	3.75	2	6.5	1	N/A	N/A	2	0
Tumblong	690	0	N/A	5	1	N/A	N/A	2	0
All Forests	144 200	306.25	14	226	9	51.67	3	19	15

*Kavanagh and Stanton (1998).
#does not include species specifically targeted by the nocturnal surveys (nocturnal birds and arboreal marsupials).
N/A = no sample.

Table 5. Effective detection methods for selected species/genera/tribe. Data are the number of records by that method during this study. N/A indicates that the genus was identifiable to species by that method.

Species	Nocturnal survey	Hair trapping	Box trapping	Opportunistic records
Tachyglossus aculeatus				8
Antechinus stuartii			9	
Antechinus swainsonii			3	
Perameles nasuta	3			1
Vombatus ursinus	8	2		16
Trichosurus vulpecular	89			3
Trichosurus caninus	44			
Macropus giganteus	15			27
Macropus robustus	1			1
Macropus rufogriseus	10			18
Wallabia bicolor	27	127		22
Rattus fuscipes		22	104	
Oryctolagus cuniculus	7			>10
Canis familiaris familiaris	3			2
Canis lupus dingo	5			
Vulpes vulpes	5			13
Felis catus	2	4		4
Genera				
Antechinus	3	9	N/A	
Trichosurus	N/A	114		
Rattus	1	N/A	N/A	
Canis	6	20		8
Tribe				
Conilurine rodents	1	3		

the most commonly hair trapped species. Many other species were not detected by hair traps, notably *P. nasuta* and *V. vulpes*.

The effort and return for each of three methods is presented in Table 4. The return for opportunistic records and for the literature and database records is also included but the effort was not easily quantifiable and has been omitted. No single detection method detected all species. Details of the species that were detected by each method are provided in Table 5.

Tracks of an unidentified Potoroo *Potorous* sp. found in Bago State Forest. Scale provided by a one dollar coin. Photography by M. Stanton.

DISCUSSION

Species accounts

Monotremes

The Platypus *Ornithorhynchus anatinus* was recorded once opportunistically during the survey in a small creek in Mannus State Forest. Other records exist for Tumut and Bungongo, in even smaller creeks. The species possibly occurs in more of the small waterways of the region which have their sources in State Forest or Kosciuszko National Park. Carrick (1995) considered the species was probably extinct within the region and generated a distribution map reflecting this view. Grant (1992) and Menkhorst (1995) presented records from along much of the length of the Murray and its upper tributaries. Ellis and Ethridge (1993) also correctly modelled the species distribution throughout the area.

The Short-beaked Echidna *Tachyglossus aculeatus* was recorded in less than half of the State Forests during this survey. It was not specifically targeted by the survey and was only detected in the larger forest areas. Records from other sources are scattered through the smaller forests of the region. The predictive model of Ellis and Ethridge (1993) suggests that it may occur throughout the region.

Marsupials

FAMILY DASYURIDAE

Only three *Antechinus* species were recorded in the region. *Antechinus* were found in most State Forests except for the smallest remnants. The exact distribution of each species is undetermined because of similarity between hairs (Brunner and Coman 1974) and the reliance of this study on hair traps. Both *Antechinus stuartii* and *Antechinus swainsonii* occur in Bago and Maragle.

Antechinus flavipes appears to be restricted to the dryer low elevation forests.

Given that no pitfall trapping was used, it remains possible that the Fat-tailed Dunnart *Sminthopsis crassicaudata*, and/or the Common Dunnart *Sminthopsis murina* occur in the forests of the region. Pitfall trapping is more effective for detecting small dasyurids, particularly dunnarts and planigales (Read 1985). No records were made of the Brush-tailed Phascogale *Phascogale tapoatafa* although it was specifically targeted by this survey. There appears to be suitable habitat. It is known to occur in an area to the south-west of the study region in Victoria. The Victorian population appears to be constrained by elevation (always below 700 metres) and rainfall (greater than 500 mm) (Menkhorst 1995). Given the proximity to Victoria this is probably the most suitable habitat model for the species in the Tumbarumba Hardwood Region. Such habitat was sampled during this study and falls outside the principal area of timber production for the region.

Spotted-tailed Quolls *Dasyurus maculatus* remained undetected in the forests of the region although the NSW NPWS Wildlife Atlas has a record from cleared land near Tumut. Similarly there are no recent records of the Eastern Quoll *Dasyurus viverrinus* which historically occurred in the area (Rolls 1969). Quolls have proven to be detectable by hair trapping in other studies (Kavanagh and Stanton 1995). If they are present, it seems likely that they occur at low abundance only.

Family Peramelidae

Long-nosed Bandicoots *Perameles nasuta* were recorded four times. The species is easily detected during nocturnal surveys by its sneezing grunt-like call. It is detectable by hair trapping but some authors (Menkhorst and Seebeck 1995; Bennett 1990 and Loyn *et al.* 1980) suggest that it is often trap shy. Given the lack of records and an apparently adequate survey effort during this study it would appear to be an uncommon inhabitant of Bago and Maragle State Forests and is a locally significant species on the western edge of its geographical range. All record localities were forested with Snow Gum *Eucalyptus pauciflora* or Swamp Gum *Eucalyptus ovata* communities and had a dense understorey. Similar habitat also occurs in Kosciuszko National Park, Buccleuch State Forest and small areas in Bungongo State Forest.

Menkhorst and Seebeck (1995) presented records of *P. nasuta* from along the Murray River at low elevations. Riverine habitat was not surveyed in this study. Possibly Long-nosed Bandicoot populations persist in similar habitat.

Family Vombatidae

The Hairy-nosed Wombat *Lasiorhinus krefftii* once occurred in the west of the region but is now presumed locally extinct. The Common Wombat *Vombatus ursinus* still occurs through much of the region although it appears to be absent from many of the smaller forest remnants.

Family Potoroidae

The historical range of two species of bettongs has been interpolated to cover the region (Ellis and Etheridge 1993). No definitive evidence of any species in this family was found during this survey or by any other recent survey. However, three sets of hind foot prints in soft mud were found and photographed. These were in the north eastern part of Bago State Forest at an elevation of approximately 1 050 metres. All three sets were within 0.5 m of each other and appeared to have been made by more than one animal or an animal passing the same spot more than once. Each print measured approximately 75 mm long. They were most probably made by a potoroo (Barbara Triggs, pers. comm.) although a young macropod cannot be completely discounted.

Family Macropodidae

Four species were detected during the survey. The most widely distributed was the Swamp Wallaby *Wallabia bicolor*, which was detected in every State Forest of the region. It was commonly detected by hair trap and during the nocturnal survey.

The Eastern Grey Kangaroo *Macropus giganteus* was also widespread and abundant in some forests but was not detected in the native timbered portions of some State Forests. It may occur in those also given that it was observed in nearby pine plantations. *Macropus giganteus* was only detected below 900 metres.

Red-necked Wallabies *Macropus rufogriseus* had a limited distribution, occurring in only the higher elevation forests (no records from below 700 metres) and apparently having a closer association with forest, particularly unburnt forests (no records in recently or heavily burnt areas) than *M. giganteus*. By contrast, Menkhorst (1995) reported no records for this species in the adjacent area of Victoria.

All three species were noted to occupy pine plantations which may provide shelter and usually have wide cleared road sides which produce good grass. Newly planted pine is usually fenced off to protect the growing pine tips from browsing by wallabies (pers. comm. Bob Gay, District Forester).

The Common Wallaroo *Macropus robustus* was recorded only from three State Forests of the region and Kosciuszko National Park. Six dead specimens found in Pulletop State Forest may represent an isolated remnant population. Given that these six specimens had been shot (without permission or knowledge of State Forests staff) as they came to the only dam in the State Forest, the future of this population may be in doubt. The remaining records from Tumut and Bungongo State Forests may represent part of a larger population spread along the western escarpment of the Southern Tablelands.

Eutherians

FAMILY MURIDAE

The only positively identified murid was the Bush Rat *Rattus fuscipes*. Some hair specimens which probably came from this species could only be identified as *Rattus*. Given the abundance of *R. fuscipes* detected by trapping (up to 44% of traps), it seems likely that the species is widespread in the moist elevated forests of the region.

Mastacomys fuscus is considered difficult to trap but predator scats can be particularly useful in locating populations of *M. fuscus* as the teeth and hair of this species are easily distinguished from those of other rodents (Wallis *et al.* 1982). A limitation of this survey was that predator scats were not found in abundance. Wallis *et al.* (1982) also found that *M. fuscus* were trapped only when other mammals which were competing for traps (*Rattus rattus, R. fuscipes, A. stuartii, A. swainsonii* and *Mus domesticus*) had been removed. In this study there were relatively large numbers of *R. fuscipes* captured at some of the *M. fuscus* trapping sites (up to 44%). These were not removed and this may have reduced the chances of trap success for *M. fuscus*.

Introduced species

Ten introduced species were detected in the forests of the region (Table 1). At least three were partly or completely domestic animals (cattle, sheep and some canids). Two additional species may occur within native timber State Forests but have only been detected in pine plantations nearby (Black Rat *Rattus rattus* and Brown Hare *Lepus capensis*). The distribution of pigs, cats and foxes may be under-represented by this study judging by anecdotal information from local forestry workers.

Survey effort and techniques

No single method accounted for records of all species and the two methods that targeted ground-dwelling mammals had the lowest species return of all. Hair traps proved to be of limited usefulness in this study with only two commonly detected indigenous species (*W. bicolor* and *R. fuscipes*) and most other samples only identifiable to genus. Many species were not detected at all including *P. nasuta*, three *Macropus* species, *T. aculeatus*, *O. cuniculus* and *V. vulpes*. No species was exclusively detected by hair traps. While the return from hair traps was low, the return between areas was reasonably consistent. *Wallabia bicolor* was detected by this method in every State Forest. More species were detected in the areas where more effort was used. Additionally, no high level training is required for staff who set or retrieve the traps, however, significant training and experience is required for acurate hair identification. The cost of hair identification is high and the data are not immediately available for workers while still in the field. Hair traps were also limited in usefulness by a lack of good local reference material, only a single design of hair trap used on the ground and no allowance for follow-up work with more discerning detection methods to investigate unidentified rodent and marsupial records.

Small mammal trapping specifically targeted *M. fuscus* and was not expected to detect a wide range of species. This proved to be the case, however it was important as the only method that positively identified *A. stuartii* and *A. swainsonii*. It is also one method that would be likely to detect small conilurine rodents and identify them to species level. For these reasons small mammal traps are an indispensable part of forest fauna surveys, however they do present problems with hardware costs and labour costs for surveys attempting to cover large areas.

Small mammal traps were limited in usefulness because they were applied to only one task. They could have been usefully employed as a follow-up to hair trapping, for example on sites where hairs from small conilurine rodents were collected or as a general survey tool.

The nocturnal survey yielded a high number of ground-dwelling mammal species, however the results were somewhat inconsistent. It

appears to have been the best method to detect canids and combined with the opportunistic records, was the only detection of *M. giganteus, M. robustus, M. rufogriseus, P. nasuta* and *O. cuniculus*. Nocturnal surveys are labour intensive and require experienced people. Results can be compromised more easily by weather and by physical variation in the habitat being surveyed. However, given that nocturnal survey in this study detected a wide range of species, it can be considered an essential component of forest fauna surveys.

In this study the nocturnal survey was limited in usefulness by the fact that it was not targeting ground-dwelling mammals and thus utilized more listening and owl playback (see Kavanagh and Stanton 1998) and less spotlighting than might otherwise have been used.

Predator scat did not provide much useful information in this study because so few were found. Barker *et al.* (1994) found that most species were detected in the first 200 scats collected in each of two study sites on the New South Wales north coast, considerably more than the 37 found in this study. Wallis *et al.* (1982) and Brunner *et al.* (1977) have found that predator scat searches are the most efficient way of finding populations of some animals such as *M. fuscus*.

CONCLUSIONS

The possible presence of *Potorous* sp., *Pseudomys fumeus* and *Mastacomys fuscus* in Bago and/or Maragle State Forests requires further investigation particularly given the unconfirmed observations of the first two species occurring in the area. More intensive predator scat searches would be useful in detecting these species. Further investigation of *Phascogale tapoatafa* would seem to be unproductive given their likely habitat range outside of the commercially harvested forest types.

The techniques of hair trapping, small mammal trapping and nocturnal survey all had a role to play in the broad area surveys of forest fauna. It is important to recognize the limitations of each method and how the methods can complement each other. Hair traps were a reliable method for a small range of species in this study *(W. bicolor* and *R. fuscipes)* but if used early in a study could allow a more efficient allocation of other survey methods. Small mammal traps are also useful for a limited range of species, particularly rodents and small marsupials, most of which are not identifiable to species level from any other method. Nocturnal survey appears to be the only efficient method of surveying for large mammals, particularly *Macropus* spp. Opportunistic records collected while in an area can be valuable for filling gaps in the known distribution of some species. Predator scat collection is a useful technique for some study areas but would need to be collected on a larger scale than was done in this study.

A comprehensive study of mammal trapping techniques is required to determine the most efficient method of conducting surveys such as this one. Clearly no single technique is suitable, however the levels of use appropriate for different kinds of studies needs to be clarified.

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